# Assessment of the Source of High Nitrate Concentration in the Pretty Prairie Well Water Supply

A report for the
City of Pretty Prairie

Donald O. Whittemore

Kansas Geological Survey
The University of Kansas
Lawrence, Kansas
July, 2014

## ACKNOWLEDGMENTS

Masato Ueshima of the Kansas Geological Survey analyzed the water samples from the City of Pretty Prairie sent to the Kansas Geological Survey. The author appreciates the comments and edits of Tim Boese, Manager of Equus Beds Groundwater Management District No. 2, who reviewed a draft of the report.

## INTRODUCTION

The city of Pretty Prairie requested the assistance of the Kansas Geological Survey (KGS) in assessing the source of increasing nitrate concentration in the water from the city supply well. The nitrate concentration has increased to levels substantially greater than the maximum contaminant limit (MCL) of 10 mg/L as nitrate-nitrogen ($NO_3$-N) for public supplies of drinking water.

Pretty Prairie is located in south-central Reno County in the southwest corner of Equus Beds Groundwater Management District No. 2 (GMD2) (Figure 1). Groundwater use in the Pretty Prairie area is primarily from unconsolidated sands and gravels in the High Plains aquifer. The depth from land surface to the underlying Permian bedrock (shale and siltstone) ranges from about 60 ft to 100 ft, although there are areas where depth to bedrock is less than 20 ft below land surface. The static water level is usually about 15 to 30 ft below land surface, although static water level is as high as less than 5 ft below land surface at monitoring well site EB502 and as low as 60 feet below land surface at site EB509. The general groundwater flow direction in the area of the city (within a mile of the city boundaries) is towards the east and northeast based on Fig. 2 in Townsend (1999).

Nitrate concentration in the groundwater has been known to exceed the MCL within parts of the area of Figure 1 since the 1990s based on the monitoring well network of GMD2. GMD2 studied the distribution and source of the nitrate concentration and reported that “the use of agricultural chemicals for the production of dryland and irrigated crops was identified as the primary non-point source” (Dealy, 1995). The study included the use of nitrogen isotopes in the nitrate source assessment. A later study by the KGS (Townsend, 1999) that focused on the Pretty Prairie area and that also used nitrogen isotopes came to a similar conclusion as the Dealy (1995) investigation; Townsend (1999) stated that “Use of nitrogen-15 indicates a predominantly fertilizer source for the nitrate.”

## METHODS

The KGS suggested collection and analysis of groundwater samples from selected wells across the city of Pretty Prairie could provide information useful for comparison with previous chemical data and for determination of the potential of within city sources of nitrate. This approach was recommended as appropriate before needing to consider more involved sampling and analysis for nitrogen isotopes.

The City of Pretty Prairie collected samples of groundwater from five wells (Figure 2). The well locations included a well to the west of the city at the eastern end of the golf course (GC), two wells within the city to the east of the grain storage silos (PPHS and LR), a well south of the city limits (just to the south of W Pretty Prairie Road – EG), and a well just to the east of the southeast corner of the city (SCS). The wells within the city were chosen to be downgradient of where the former north-south railroad line along Sante Fe Avenue would have passed near to the grain silos, a potential area where fertilizer might have been offloaded in the past. The water samples were analyzed at the KGS for specific conductance and dissolved concentrations of nitrate, chloride, and sulfate (Table 1). The City of Pretty Prairie provided data for analyses of water from the city supply well (Table 2). These data were assessed and compared to the results in the reports by Dealy (1995) and Townsend (1999) and in other reports.

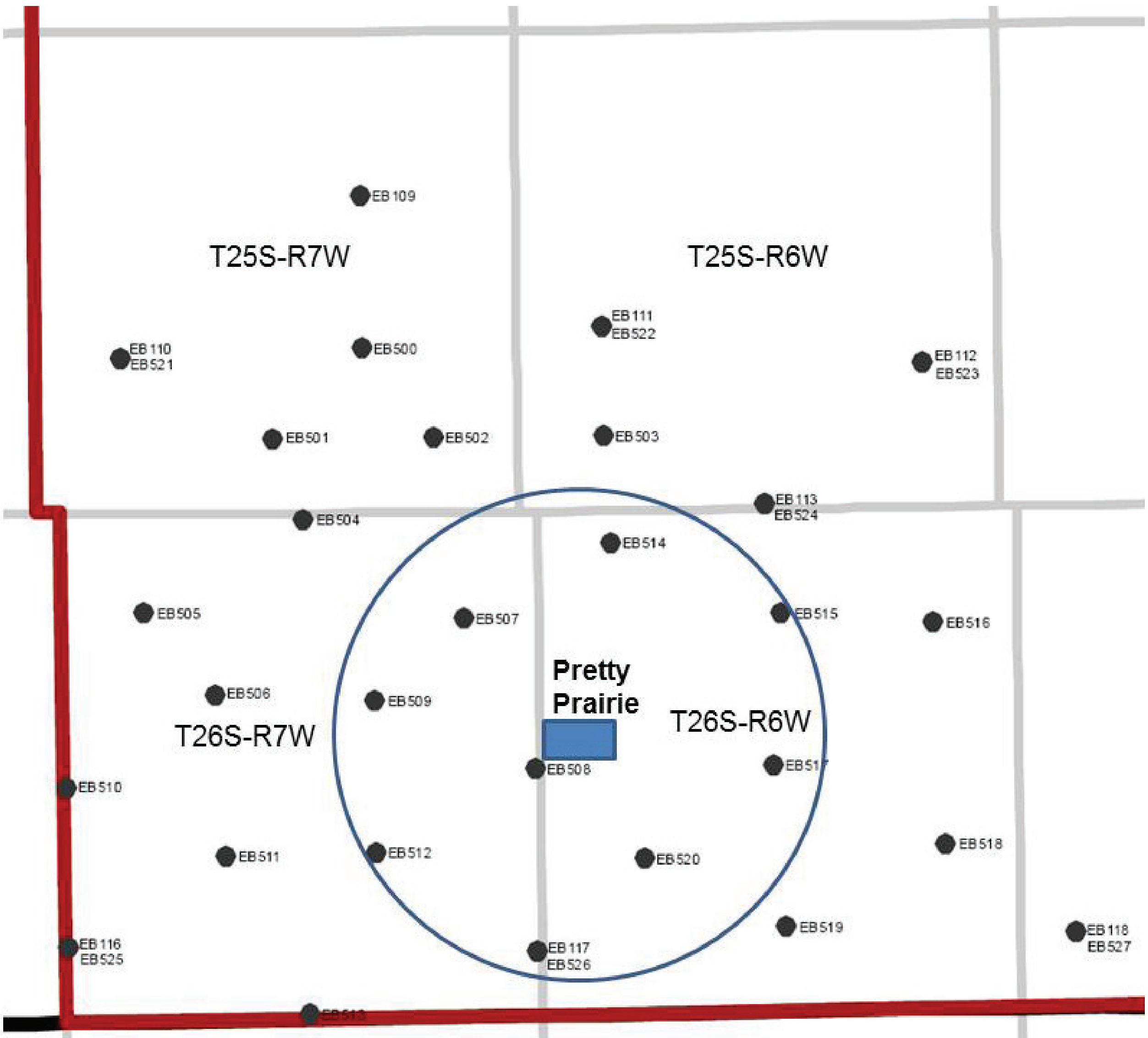


Figure 1. Southwest portion of GMD2 in south-central Reno County that includes the City of Pretty Prairie. The four squares outlined by the gray and red lines are 36-square mile townships (labeled with township and range numbers) that are each 6 miles across. The circle is approximately 6 miles in diameter and encloses Pretty Prairie and the locations of GMD2 EB monitoring wells discussed in this report. The bold red lines are the boundaries of the southwest corner of GMD2.

Table 1. Chemical data for groundwater samples collected by the City of Pretty Prairie from wells within and adjacent to the city in January 2014. Analyses by the Kansas Geological Survey.

| KGS lab number | Site name | Legal location[a] | Sp.C.[a] µS/cm | Chloride (Cl) mg/L | Sulfate ($SO_4$) mg/L | Nitrate-nitrogen ($NO_3$-N) mg/L |
|---|---|---|---|---|---|---|
| 2014001 | EG | 26S-06W-19BAB | 424 | 13.8 | 25.4 | 24.8 |
| 2014002 | GC | 26S-07W-13DDA | 398 | 8.6 | 28.0 | 14.3 |
| 2014003 | LR | 26S-06W-18DCAB | 536 | 21.6 | 20.1 | 20.3 |
| 2014004 | PPHS | 26S-06W-18DBC | 462 | 20.5 | 26.7 | 17.3 |
| 2014005 | SCS | 26S-06W-17CCC | 513 | 24.5 | 21.3 | 20.9 |

[a] Township-range-section and quarters from large to small based on USGS system (A = NE, B = NW, C = SW, D = SE)
[a] Specific conductance at 25 ºC

Table 2. Chemical data for groundwater samples collected from the public supply well of the City of Pretty Prairie.

| Collection date | Sp.C.[a] µS/cm | Chloride (Cl) mg/L | Sulfate ($SO_4$) mg/L | Nitrate-nitrogen ($NO_3$-N) mg/L (range) |
|---|---|---|---|---|
| 3/23/2009 | 400 | 11 | 25 | |
| 10/17/2011 | | | | 13.6-16 |
| 4/10/2012 | 440 | 10 | 24 | |
| 8/30/2012 | | | | 15.5-18.6 |
| 11/26/2013 | | | | 18.6-20.2 |

[a] Specific conductance at 25 ºC

**DISCUSSION**

All of the samples collected in January 2014 within and adjacent to Pretty Prairie contained nitrate concentrations exceeding the public drinking water MCL of 10 mg/L (Table 1). The waters were all freshwaters with estimated total dissolved solids (TDS) concentrations in the range 240-320 mg/L (based on multiplying the specific conductance by 0.6, an approximate factor derived from the complete major inorganic analyses in Townsend [1999]). Although chloride and sulfate concentrations were higher than in the public supply well (Table 2), they were all relatively low for south-central Kansas.

The nitrate concentrations in the five well samples listed in Table 1 were in the general range of the nitrate concentrations in samples collected from the public supply well during the last few years (Table 2). The nitrate concentrations of the two samples within Pretty Prairie to the east of the grain silos (samples LR and PPHS) were in the range of the values for the public supply well. Thus, no significant local nitrate source appears to be present in the center of the city. The nitrate concentration in the well in the golf course area to the west of the city (sample GC) is lower than the values for all of the other four wells and for the last two years of samples from the city supply well. Therefore, the source does not appear to be specially associated with the golf course (opened in 1996). The nitrate level in the water from the well located just outside the southeast corner of the city (sample SCS) is about the same as for the wells within the city (including the public supply well). The well water with the highest concentration (sample EB) is located just to the south of the city near two agricultural fields irrigated by center pivots (the dark green half circles to the south of the southwest part of the city shown in Figure 2).


Figure 2. Satellite map of the Pretty Prairie area taken between July 2010 and September 2011 (from Bing Maps). The color of the center pivot areas and wheat fields suggests that the photograph was taken during the summer after wheat harvest. The diameter of most of the full center pivot circles is 0.50 mile. The approximate locations of the five wells from which water samples were collected in January 2014 are represented by the yellow-filled circles; the labels by the circles correspond to the site names in Table 1 and the points in Figure 3.

The nitrate and chloride concentrations of the five wells in the Pretty Prairie area sampled in January 2014 plot within the general range of the concentrations in samples from the GMD2 monitoring wells within a 3-mile radius of Pretty Prairie (Figure 3). The nitrate source in all of the GMD2 wells (except EB526D) within the 3-mile radius of Pretty Prairie with greater than 10 mg/L nitrate-nitrogen concentration was shown to be primarily derived from agricultural fertilizer (Dealy, 1995). The sample from EB526D had a nitrogen isotope signature in the range between fertilizer and animal waste nitrate sources. Dealy (1995) stated that "well 526D is near an abandoned farmstead and as such is suspect of being impacted by both animal and human wastes." Both the nitrate and chloride concentrations have decreased during 2007-2012 in water from well EB526D comparison to the values for these constituents in the 1993 sample collected for nitrate and nitrate isotope determination.

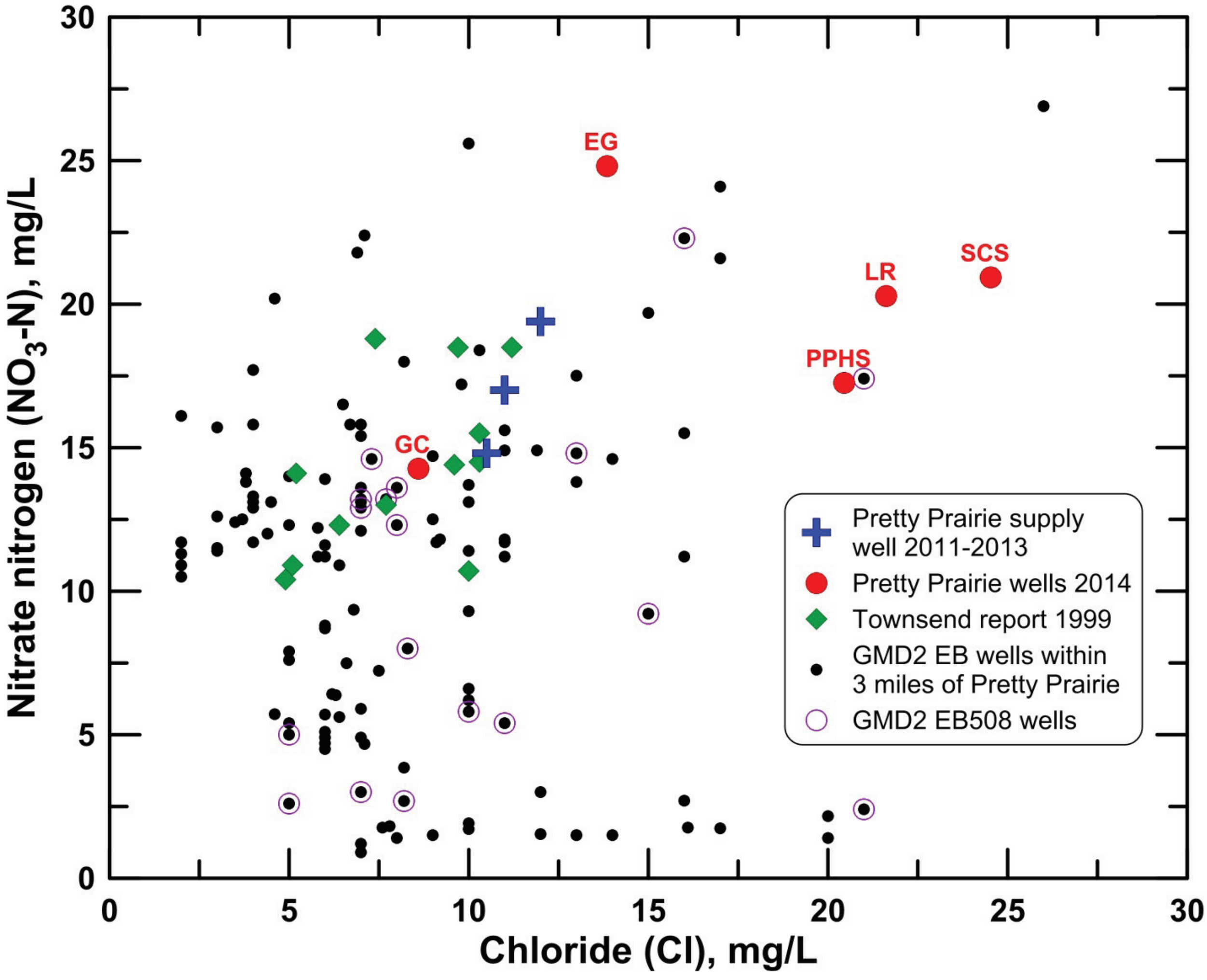


Figure 3. Nitrate versus chloride concentration for groundwaters within Pretty Prairie and the surrounding area within an approximately three-mile radius. The nitrate values for the three points for the city supply well represent the averages of the three ranges for specific dates in Table 2; the chloride values are estimated based on the analyses in Table 2. The Pretty Prairie well data for 2014 are from Table 1. The data for GMD2 EB wells are from GMD2; the EB508 wells are located south of the golf course just outside the southwest corner of the city.

The chloride concentration in the wells in the city area collected in January 2014 is not as high as would be expected if a human or animal waste source were the primary origin of the nitrate. For example, Townsend (2007) found that a variety of human and animal waste sources (wastewater from the sewage treatment plant, abandoned septic systems, and farm animal wastes) appeared to be the origin of nitrate-nitrogen concentrations exceeding 10 mg/L in groundwaters with nitrogen-15 isotopic values greater than 10 per mil (‰) in the city of Lincolnville, Kansas. The chloride concentration in groundwaters with high nitrate concentration in Lincolnville exceeded 30 mg/L and in most waters exceeded 60 mg/L. In comparison, many of the well waters with nitrate-nitrate concentration below several mg/L contained a chloride concentration less than 30 mg/L.

The three well water samples within and just to the east of Pretty Prairie (samples PPHS, LR, and SCS) have somewhat greater chloride concentrations than the golf course and EG samples and most of the GMD2 monitoring well samples. This could be related to recharge of well water used for lawn watering that was affected by evapotranspiration concentration of dissolved solids and recharge of precipitation affected by road salt applied to the city roads. The distribution of nitrate and chloride concentrations does not indicate a substantial source of these constituents from leaching of remnant waste in individual septic systems that may have been present before the installation of the wastewater collection and treatment facilities of the city.

The nitrate concentration in groundwater sampled from the GMD2 monitoring wells within a 3-mile radius around Pretty Prairie (Figure 1) ranges from background levels (less than 3 mg/L) at wells EB507C and EB515C to over 20 mg/L at wells EB509A and EB514C in 2012 and at wells EB507A, EB508C, and EB514A in 2007 (Figures 4-6). The nitrate concentration in samples from monitoring wells in the depth range 60-71 ft shows a generally increasing trend (Figure 5). The monitoring wells with nitrate-nitrogen concentrations greater than 10 mg/L typically are near center pivot irrigation systems and what appear to be wheat fields in satellite photographs. The monitoring well with the lowest nitrate concentration (EB515C) is primarily surrounded by what appear to be grassed fields and a drainage area with grass and trees. The low nitrate concentration at well EB507C could be partly related to the screened interval of 101-111 ft below land surface, which is at the bottom of the High Plains aquifer at a greater depth than any of the other monitoring wells within a 3-mile radius of Pretty Prairie.

GMD2 monitoring well site EB508 is located south of the golf course and across the road from the southwest corner of Pretty Prairie. Two wells exist at the site: EB508A screened at 21-31 ft and EB508C screened at the bottom of the High Plains aquifer at 61-71 ft below land surface. The nitrate-nitrate concentration in samples from the shallow well has generally decreased from about 8-9 mg/L in 1992-1993 to 2.4 mg/L in 2012 (Figure 4). Thus, the recent land use in the area close to the well does not appear to be a significant source of nitrate but rather has allowed recharge to slowly dilute higher nitrate concentrations that occurred in the past. In contrast, nitrate-nitrogen concentrations in all samples from well EB508C have been greater than 10 mg/L, and have increased from the range 12.3-14.8 mg/L in the 1990s to 17.4-22.3 mg/L in the last two samplings (2007 and 2012) (Figure 5). The data suggest that nitrate sources farther from the immediate area around the well site are reaching the groundwater, migrating to greater depths below the water table, and then moving with groundwater flow to the site. The generally greater nitrate concentrations at the EB well depths of 60-71 ft in comparison with those at the shallower EB wells (Figures 4 and 5) also support this process.

The groundwater flow direction in the vicinity of Pretty Prairie is toward the east and northeast based on Figure 2 in Townsend (1999). Cultivated fields, including center pivot systems, on which nitrogen fertilizers would be applied are located in the upgradient flow direction from the city and the location of the public supply well. Precipitation recharge and irrigation return flow could carry dissolved nitrate not completely used by crops to below the root zone to the water table. Dispersion of recharge by groundwater flow, including along the downward curved flow lines locally created during pumping around irrigation and other wells, would move the high-nitrate concentration to deeper in the aquifer. The high-nitrate groundwater would then flow faster in the more permeable portions of the aquifer (the sands and gravels) in which water supply wells are typically screened than in the less permeable fine sands, silts, and clays.

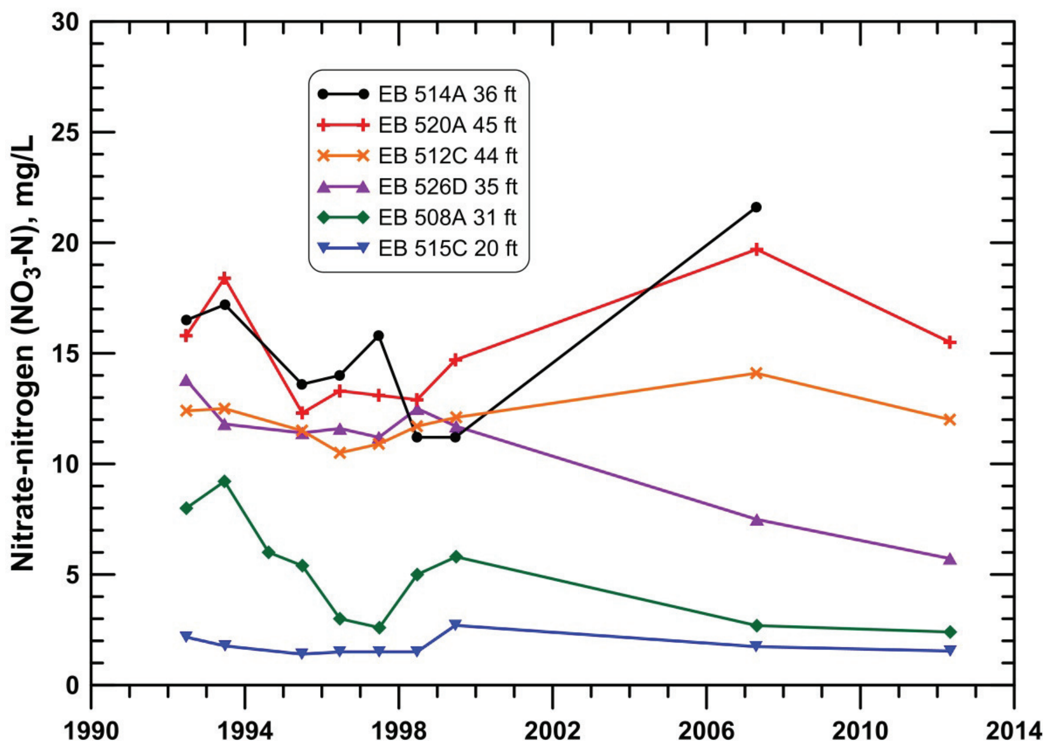


Figure 4. Variation in nitrate concentration in GMD2 monitoring wells screened at shallow depths (20-45 ft) in the High Plains aquifer within a 3-mile radius of Pretty Prairie.

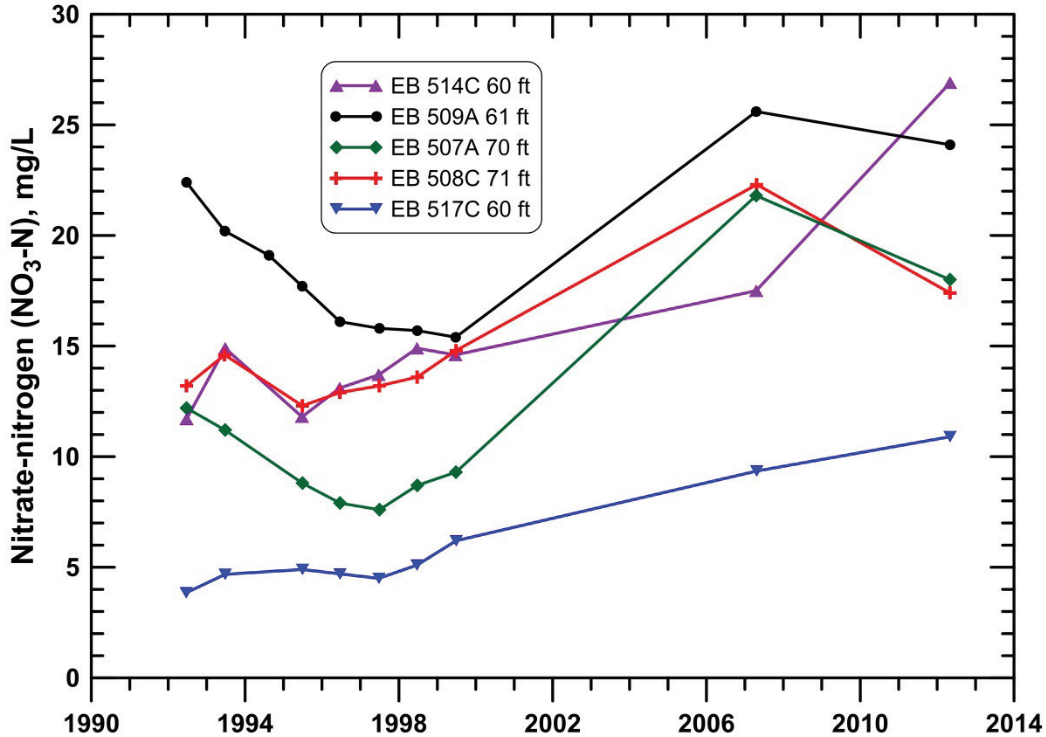


Figure 5. Variation in nitrate concentration in GMD2 monitoring wells screened at depths of 60-71 ft in the High Plains aquifer within a 3-mile radius of Pretty Prairie.

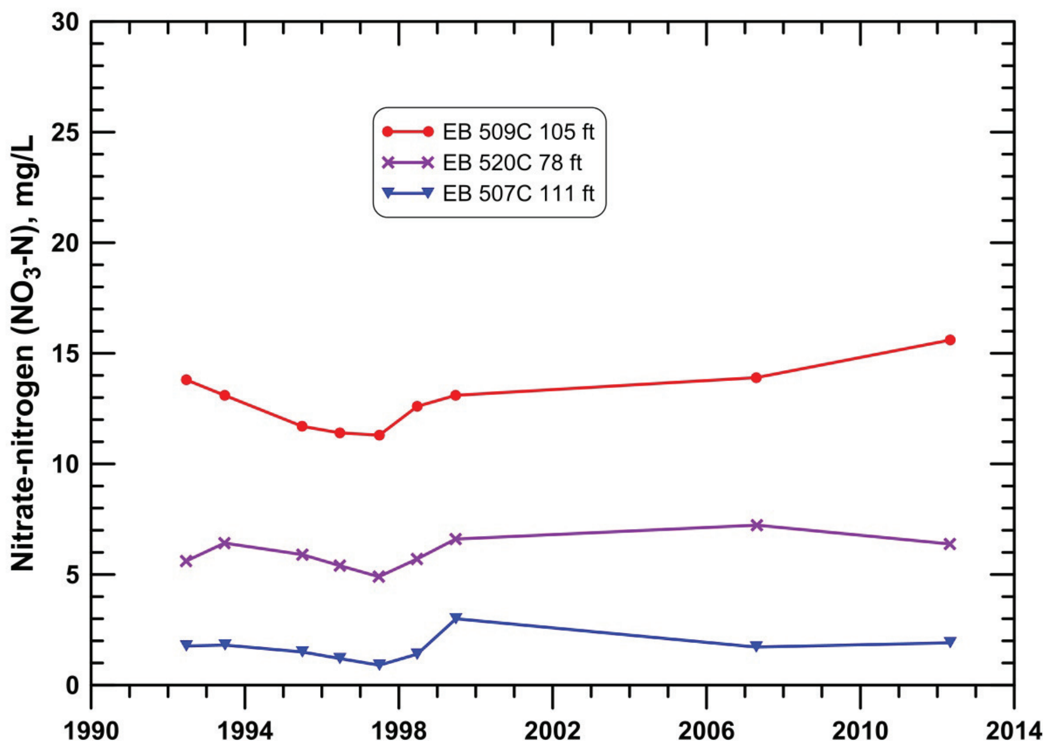


Figure 6. Variation in nitrate concentration in GMD2 monitoring wells screened at depths of 78-111 ft in the High Plains aquifer within a 3-mile radius of Pretty Prairie.

The Pretty Prairie municipal supply well located to the northeast of the city is in the northeast corner of a rectangular agricultural area that appears to be a wheat field. Center pivot irrigated fields are located to the northwest and west-northwest of the city supply well. These could provide local sources of fertilizer derived nitrate in the groundwater. The golf course and some lawns within the city are probably fertilized and lie in an upgradient direction of groundwater flow from the city supply well. Although these could provide some nitrate to the groundwater, it is noted that the nitrate concentration in the groundwater from the well immediately downgradient of the golf course had the lowest concentration of any of the five samples collected in the city area in January 2014. The nitrate-nitrogen concentration in this well water was 14.3 mg/L in comparison with the range of 18.6-20.2 mg/L for the city supply well in 2013.

Pumping by the city well would create a cone of depression in the water table that could result in drawing in high-nitrate water originating from below the nearby agricultural fields and possibly below lawns in the city. The city supply well is screened in sand and gravel at 76-98 ft in the bottom portion of the High Plains aquifer. Although shallower parts of the aquifer at the city well also contain sand and gravel, some thin clay layers and streaks occur within this zone. In addition, the 62-66 ft depth interval at the well consists of fine sand and clay, with the clay comprising approximately 50% of the interval. Thus, some of the water drawn in by the city well over time could also possibly derive from groundwater flow through the sand and gravel zone in which the well is screened that was recharged with high nitrate water farther to the west and southwest of the city.

## CONCLUSIONS

High nitrate concentration is pervasive in much of the groundwater throughout the Pretty Prairie region and is generally associated with areas of cultivated fields where agricultural fertilizers are applied. Studies by Dealy (1995) and Townsend (1999) identified the primary source of the nitrate contamination as fertilizer based on nitrogen isotopes. The chloride concentration associated with the high nitrate groundwater in the Pretty Prairie region as well as in the area within and immediately adjacent to the city is also consistent with a fertilizer source and not a human or animal waste source. The source of the high nitrate concentration in the city does not appear to be derived from a local area near the grain silos in the center of the city.

The fertilizer source of nitrate in the water from the city supply well is expected to be derived primarily from agricultural application but may possibly include some lawn fertilizer. Agricultural fields and city residences as well as a golf course are within the general direction of groundwater flow towards the city well. However, fertilizer associated with the golf course does not appear to be a significant source of nitrate based on the distribution of nitrate concentration in the groundwater in the area. Although some of the high-nitrate water could have originated from local fields and possibly a small amount from some lawns, some could also be from agricultural fields farther upgradient (in groundwater flow direction) from west and southwest of the city; the groundwater from these areas could be flowing through the most permeable portions of the High Plains aquifer through the city area to the city supply well. Determination of the amount of fertilizer applied to the lawns in the city in comparison with the amount applied to agricultural fields within a couple miles in the upgradient regional flow direction and the cone of depression in the water table around the city well when it is pumping might provide a rough estimate of the relative contribution of the fertilizer sources.

Reducing the amount of fertilizer applied in the area upgradient of the city supply well could be a potential approach to decreasing the level of nitrate concentration in the groundwater drawn in by the well. The decrease in nitrate concentration in groundwater sampled from the shallow well at GMD2 monitoring well site EB508 could reflect such a reduction, based on the replacement of the former agricultural land use with a golf course and grassed area. Reduction of nitrate leaching from cropland through farm management practices has been reviewed and assessed in Dzurella et al. (2012). The beneficial effects of changing agricultural land-use practices on the nitrate concentration of groundwater used for municipal supply is being demonstrated for the city of Woodstock in Ontario, Canada (Haslauer et al., 2005). Alternative cropping and fertilizer practices are being used to reduce the amount of nutrients applied to fields in the upgradient direction of groundwater flow to the Woodstock municipal well field. However, although the nitrate concentration of the groundwater could be decreased by such practices in the Pretty Prairie area, the relatively shallow water table and thin saturated thickness of the aquifer, in addition to the wide-spread agricultural land use involving fertilizer application, could make it difficult to bring the current nitrate concentration, which is about twice that of the MCL, down to below the MCL for drinking water.

## REFERENCES


Dealy, M.T., 1995, Investigation of nitrate-nitrogen concentrations in the Equus Beds aquifer, southeast Reno County, Kansas: Equus Beds Groundwater Management District # 2, Halstead, KS, Water Quality Investigation 95-
01, 148 p.

Dzurella, K.N., Medellin-Azuara, J., Jensen, V.B., King, A.M., De La Mora, N., Fryjoff-Hung, A., Rosenstock, T.S., Harter, T., Howitt, R., Hollander, A.D., Darby, J., Jessoe, K., Lund, J.R., & Pettygrove, G.S., 2012, Nitrogen source reduction to protect groundwater quality. Technical Report 3 in: *Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature*. Center for Watershed Sciences, University of California, Davis. http://groundwaternitrate.ucdavis.edu/files/138956.pdf.

Haslauer, C.P., Rudolph, D.L., Thomson, N.R., Walton, R., and Misek-Evans, M., 2005, Impacts of changing agricultural land-use practices on municipal groundwater quality. *in* Thomson, N.R., (ed.) *Bringing Groundwater Quality Research to the Watershed Scale* (Proceedings of GQ2004, the 4$^{th}$ International Groundwater Quality Conference, held at Waterloo, Canada, July 2004) IAHS Publication 297, 2005.

Townsend, M., 2007, Use of the nitrogen-15 natural abundance method and other chemical tracers to identify nitrate sources at Lincolnville, Kansas. Kansas Geological Survey Open-file Report 2007-13, http://www.kgs.ku.edu/Hydro/Publications/2007/OFR07_13/index.html.

Townsend, M., 1999, Evaluation of sources of nitrate in ground water near Pretty Prairie, Kansas, using nitrogen-15 isotope method. Kansas Geological Survey, Open-file Report 1999-44, http://www.kgs.ku.edu/Hydro/Publications/1999/OFR99_44/index.html.